parts, such as bulb-scales of the Shallot and fronds of *Lemna trisulca*, may be examined very easily without any such preparation.

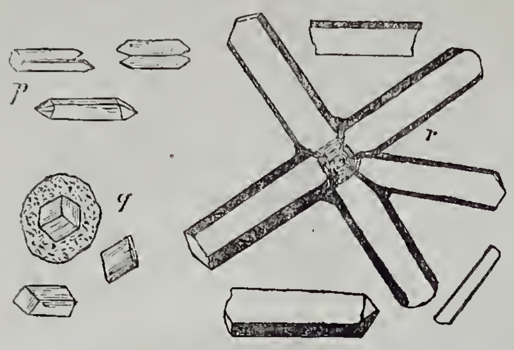

Fig. 61. *p*, Crystal Prism from ovary-coat of *Centaurea nigra*; *q*, different forms, one in its cell, from the same part of *Centaurea scabiosa*; *r*, Crystalline Cross, and three single crystals, from bulb-scale of Shallot. All highly magnified.

4. *Microscopic Interest of the Crystals.*—Of all the objects in the plant-tissues, there are none more beautiful and more likely to interest the tyro in micrographic botany than these crystals. While under examination the glassy raphides roll about in various directions, like a loose bundle of sewing-needles thrown on a table. The sphæraphides are commonly contained in distinct cells, and the crystal prisms are scattered and fixed in the direction of the fibres of the plant, but sometimes, as in the Shallot, lie across the tissue-cells. The prisms are well adapted for experiments on the polarization of light, as Colonel Horsley has often shown at the Canterbury meetings of the East Kent Natural History Society. Any of the crystals may be easily preserved, either simply dried, or in balsam or dammar, or in glycerine and other wet mediums. And when numerous slides have been collected and correctly labelled, their taxonomic interest will become evident, and thenceforth go on increasing with the increase of the collection, which may become an important one for reference as to the value of the crystals as characters in systematic botany. Thus this might well be an elegant and useful occupation, in which ladies could engage, for pleasing and instructive "half-hours with the microscope"; and which in this single subject would afford an extensive and valuable cabinet of beautiful microscopic objects, and rational researches that are not likely to be exhausted after many half-years have been thus employed. The inquiry might be extended to the development of the raphides, from the ovule and seed-leaves, to the different parts of the mature and growing plants, to their decline, death, and rottenness. For experiments of this kind the common Onagraceæ of our gardens, fields, and lanes, and the different species of *Ornithogalum*, would answer; and they might be grown for the purpose in little pots of various soils, and thus give perpetual pleasure and profit to any one with the mind and means to use the microscope thus rationally.

5. *Nature and Use of the Crystals.*—The crystals are by no means, as maintained by eminent observers, diseased or irregular products in plants, like calculi in animals, but are so truly part and parcel of the essential nature of the plant in which they occur, that it cannot be well grown without producing them, and this from the birth to the grave of the species. Numberless examples of this truth may be found in the plants of our common pools and fields; and I have often proved it experimentally in various members of the dicotyledonous orders Balsaminaceæ, Galiaceæ, and Onagraceæ, and in some Monocotyledons. The crystals are mostly oxalate of lime, with a small proportion of other earthy salts. Though this, according to Professor Douglas Maclagan, is the case with raphides, some of them appear to be phosphate of lime, according to examinations made, at my request, by the late John Davy, of these crystals in *Epilobium*, *Galium*, and *Smilax* (*Ann. Nat. Hist.*, June, 1864). And this leads us to a notice of the use of such crystals. The Sarza of the Pharmacopœia is a *Smilax* very rich in raphides and starch; and hence, probably, the well-known efficacy of this drug in those diseases, especially of the bones, in which there is a deficiency of the earthy phosphate. In like manner the Duckweeds abound in raphides and starch, and on these plants young mammalia, water-birds, and lower animals feed greedily; and no doubt this is the very pabulum best adapted for the nourishment and growth of the bones and other parts. Many animals are ever feeding on seeds in which microscopic crystals abound. Thus we come to understand some of the manifold ways in which Nature has provided for the wants of her creatures. We have seen that science too can turn these crystals to good taxonomic purpose; and it may be added that they are often the best tests of the genuineness of many vegetable drugs; such as Orris, Quillaja, Guaiacum, and Rhubarb. The false or American Sarza, being an *Aralia*, is at once plainly distinguishable by its sphæraphides from the genuine Sarza. Again, as manure, the calcareous salts which compose the crystals must be of great value; nature storing a superabundance of them in the living plant, to be restored in the dead leaves and other parts to fertilize the earth. Accordingly, we see good reason why the gardener so carefully husbands his leaf-mould; and that such plants as the Duckweeds, Fuchsias, and Willowherbs, should, from their profusion of raphides, in this respect best serve his purpose. In fine, as poor Charlotte Smith, who loved our wild flowers so well and truly, sung of them:—

"All are for use, for health, for pleasure given,
All speak in various ways the bounteous hand of heaven."

Canterbury, March 6, 1873.

in SCIENCE-GOSSIP of March, 1873, and which the French botanists called 'Crystal glands' and 'Cystoliths,' occur in several Moraceæ and Urticaceæ. Raphides are found occasionally in the same plant, together with either crystal prisms or sphæraphides, or both, as may be seen, *e. g.*, in some Pontederaceæ, Vitaceæ, Mesembryaceæ, and Melanthaceæ.

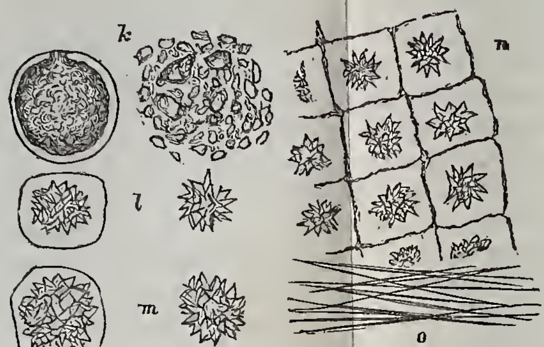

Fig. 60. *k*, Sphæraphides, one in its cell, the other crushed, from the leaf of the Nettle; *l*, Sphæraphides, one in its cell, the other naked, from the stem of *Mercurialis annua*; *m*, the same, from the leaf of *Silene maritima*; *n*, Sphæraphid tissue (magnified less than half as much as the other objects), from the leaf of *Veratrum*; *o*, Raphides, from the same leaf.

2. *Taxonomic Characters.*—As it would require a volume to do justice to this part, it can be touched but slightly here. Seeing the difficulty and fugacity of many established botanical characters, and the consequent perplexities of the student, it seems strange that systematists should not be ready to help him, by the use of any little contribution, from whatever quarter, and however novel and unexpected. But they have hitherto totally ignored the characters afforded by raphides, although these are eminently natural and constant, and often more plain and permanent, fundamental and universal, than some of the stereotyped diagnoses. In our flora, raphides are so characteristic of the dicotyledonous orders Onagraceæ, Balsaminaceæ, and Galiaceæ, that you might truly, and most briefly and sharply, define Onagraceæ as Calycifloral Exogens abounding in raphides; and so in like manner the other two orders. Some endogenous orders might be similarly characterized, while, on the other hand, there are orders —Hydrocharids, *e. g.*—regularly ex-raphidian amid their allied orders which as constantly abound in raphides. The Grape Vine and all its nearest allies of the order Vitaceæ, of which the Virginian Creeper is a familiar example, teem with raphides; and this character, frequently associated with sphæraphides, is sufficient to distinguish the Vines from the other orders of the Berberal Alliance. Even that most curious plant *Pterisanthes* proclaims by its raphides its affinity with the Vines, and so does *Leea*, though it has been removed from them by some eminent systematists, and even erected into a distinct order by Von Martius. Among our common thick-leaved window-plants, the Mesembryanthemums abound in raphides, sometimes with minute prisms, and other crystalline forms, in the same plant; and though this large genus is thus characterized, other members, such as *Glinus*, of the same order, are devoid of raphides, and hence show less relation to Mesembryaceæ than systematists have believed. Raphides are plentiful in the Hyacinths. The Cactaceæ afford large sphæraphides and often a profusion of coarse crystalline grit. The Jalap of our Pharmacopœia, being a *Convolvulus*, is quite devoid of raphides; and thus easily might it have been distinguished from *Mirabilis jalapa*, of the order Nyctaginaceæ, in which they abound, and which was so long and erroneously supposed to afford that drug. Though many Monocotyledones are raphis-bearing, several orders of them—the Grasses and Sedges for example—are devoid of raphides. Sphæraphides occur abundantly, and often very characteristically, in the New Zealand Spinach of our gardens, and in our native Goosefoot plants, in the Nettle or Hop tribe (fig. 60, *k*), annual Dog's Mercury (fig. 60, *l*), many members of the Silenal Alliance (fig. 60, *m*), the Wayfaring-tree, Water-Milfoils, and in numerous different orders besides. The well-known crystals in the Rhubarb of the Pharmacopœia are sphæraphides. Crystal prisms are plentifully produced by many Monocotyledons, as may be seen in the common cottage-garden favourite, *Iris germanica*, in the officinal sweet-scented Orris, in the bulb-scales of the Onions (fig. 61, *r*), and, among Dicotyledons, in the Guaiacum bark and Quillaja (fig. 59, *g*) of the shops. Either in the ovary or testa of our native Cynareæ and other Compositæ, as may be seen (figs. 59, *h* and *i*, and 61, *p* and *q*) in *Serratula*, *Centaurea*, *Carduus*, *Silybum*, and the Inuleæ, crystal prisms are frequent, like to, but smaller than, those of the foreign Quillaja; and in some afford good specific characters. For example, the little long prisms of *Centaurea nigra* (fig. 61, *p*) and *C. cyanus* at once distinguish these species from *C. scabiosa*, as in this last there are only those minute and short crystals, cuboid, prismatic, flat, or lozenge-shaped (fig. 61, *q*), often each within a cell, which are so very common in various orders of plants, especially Amentiferæ. The curious crossed and seemingly truncate prisms of certain species of the Onions (fig. 61, *r*) are very characteristic.

3. *How to find the Crystals.*—Of any plant already cited as affording them, scrape and mash to a pulp a bit of the leaf or other part in a drop of water on the object-slide, then press with a thin glass cover, and the crystals will be easily distinguishable under an objective of half or quarter-inch focus. Very delicate sections of the plant-tissue may be needful to show the crystals uninjured in their natural situation. Pulpy parts, like the berries of the Arums and Black Bryony, and thin transparent

an inch, and a thickness of $\frac{1}{5000}$th. But they vary much in size in different plants, being very large in the officinal Squill (*Urgenia*), very small in the Bedstraws (Galiaceæ), and of intermediate size in the Black Bryony (*Tamus communis*). I have never been able to find raphides in any British tree, though they are plentiful in many foreign trees, as, *e. g.*, the Screwpines and Vines.

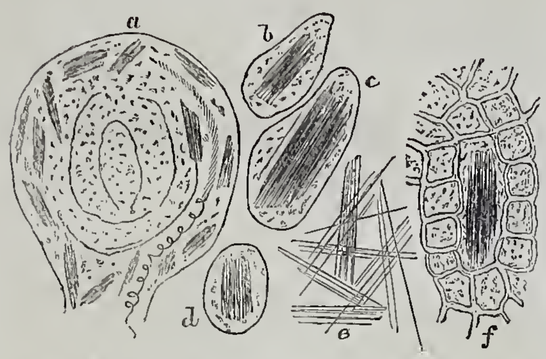

Fig. 57. Raphides: *a*, in the ovule of Fuchsia; *b*, in a cell from the berry of Fuchsia; *c*, from the berry of *Arum maculatum*; *d*, from the leaf of *Neottia spiralis*; *e*, loose from the berry of *Tamus communis*; *f*, in an intercellular space of an old frond of *Lemna trisulca*. All moderately magnified.

Biforines, fig. 58.—Sometimes the cell in which the raphides are contained is soft and viscid, like a bit of protoplasm, devoid of a distinct cell-wall, though the wall, like Mohl's primordial utricle, may be made apparent by chemical means. From such a cell, as may be often seen in some Araceæ during the microscopic examination, the raphides escape at one or both ends (fig. 58); and hence the term 'biforines' by the French botanists. The phenomenon is singularly beautiful, for the brilliant and hyaline crystals emerge from the cell with a life-like activity that is quite surprising.

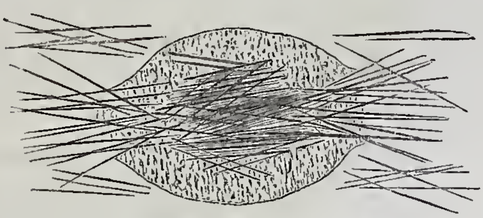

Fig. 58. Biforines from *Richardia æthiopica*.

Crystal Prisms (figs. 59 and 61) are also acicular forms, occurring either singly, or two or three partly consolidated, never, like raphides, loosely in bundles; and each prism has several flat faces, and as many angles; the tips of the crystal appearing sometimes truncate, more often pyramidal, with the base of the pyramid corresponding to the shaft; and the end may be pointed, or like a carpenter's chisel, or wedge-shaped, or sloped off obliquely from angle to angle, or from face to face of the shaft. Of the quadrangular prisms the faces may be all equal, or two of them broader than the other two; and of the three-sided prisms a transverse section of the shaft may present either an isosceles or equilateral triangle. Occasionally the shafts are shaped as if from a longitudinal cleavage, either partially or completely, through the faces or angles of the crystals. They are firmly imbedded in and along the plant-tissue, and seldom or never in a cell that is easily demonstrable. They are mostly larger, sometimes smaller, than raphides; and in *Quillaja saponaria* about $\frac{1}{100}$th of an inch in length, and $\frac{1}{1600}$th in thickness. In the Shallot (*Allium ascolonicum*) and some other Onions (fig. 61, *r*), the prisms are shorter and thicker, often apparently truncate, though sometimes plainly seen with a low pyramidal tip, having four sides; the shafts either forming crosses consolidated at the intersecting parts, or occurring singly, varying much in size, and lying across the tissue cells. In the ovary and seed-coat of Cynareæ the prisms (fig. 59, *h* and *i*, fig. 61, *p*) are much smaller, and frequently, as also in several different orders, fused together longitudinally.

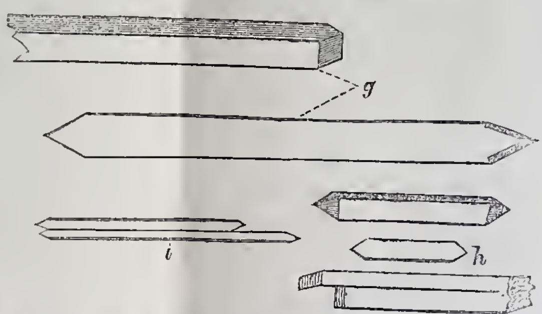

Fig. 59. Crystal Prisms, highly magnified: *g*, from *Quillaja saponaria*; *h*, from the testa of *Silybum marianum*; *i*, from the ovary-coat of *Carduus lanceolatus*.

Sphæraphides, fig. 60.—Each of these is usually a rounded conglomeration of minute crystalline granules or angular crystals, frequently smoothish, often granular or stellate on the surface, from projecting granules or points of the constituent crystals, and generally contained in a distinct cell (fig. 60). A very common diameter of the sphæraphides is about $\frac{1}{1000}$th of an inch each; often smaller, especially in several British plants; much larger in others, and larger still in some foreign species, such as the Cactus-tribe. When the sphæraphides are regularly spangled in a membraniform part, consisting mainly of their cells, I call it Sphæraphid Tissue (fig. 60, *n*); and of this beautiful examples may be seen in the leaves and inner layers of the bark of *Aralia spinosa*, common on our lawns, in the sepals of the Purple Loosestrife of our ditch-banks, and some wild Geraniums, and in the leaves—with a profusion of raphides—of *Veratrum nigrum*. Sometimes each of the sphæraphides appears as if suspended within its cell by a pedicle (fig. 60, *k*), which is not always easily seen: these, which Mr. Roper has described

(May 1. 1873)

RAPHIDES, SPHÆRAPHIDES, AND CRYSTAL PRISMS.

By PROFESSOR GULLIVER, F.R.S.

RESPONDING to the request of the editor of SCIENCE-GOSSIP, I proceed to give some account of these beautiful plant-crystals. And this the more readily because, so far as I know, it would be idle to consult our current floras and other books, including those specially devoted to microscopic objects, for correct definitions of these crystals, and the use of them as characters in systematic botany; since in those works the subject is either wholly neglected or treated so perfunctorily as still to require distinct reiteration. As space is necessarily limited, the matter must now be confined chiefly to such points as may invite and assist the student. More ample details, especially as regards my extensive and original observations on the value of raphides as characters in systematic botany, are given in my papers, epitomized in the *Popular Science Review* up to October, 1865, since continued in the *Annals of Natural History* for November of that year, and in many numbers of *Seemann's Journal of Botany*, and of the *Quarterly Journal of Microscopical Science*.

On the present occasion, the matter concerning the crystals may be treated in the following order:—1. Nomenclature; 2. Taxonomy; 3. How to find the crystals; 4. Their Microscopic Interest; and, 5. Their Composition and Use. And as we often meet with private inquiries and public advertisements for "good microscopic materials," so it will now be shown that, even in this limited department, Nature has scattered those very materials broadcast everywhere around us, whether in towns at Covent Garden, and druggists' shops, or in country fields, ditches, and lanes. In the following woodcuts, which are all copies of original drawings by me from nature, nothing is depicted that may not be seen under an object-glass of half or quarter-inch focus, and often of much less power. Of each figure the objects are magnified somewhat to the same degree, except when otherwise noted; and as their sizes are given in the text, specifications of the enlargement are not necessary for perspicuity. The student should examine some of the crystals for himself, as he may easily do in the plants now mentioned as always obtainable for this purpose. In the text, for the sake of precision and the want of English equivalents, some hard words are used; but all these are explained in most of our popular floras or manuals.

1. *Nomenclature.*—All microscopic plant-crystals were formerly called raphides, and this error, though fatal to their taxonomic value, is common now; for it is still perpetually confounding forms essentially different, and occurring, if understood in this loose and incorrect manner, almost indiscriminately or generally in numberless plants that never produce raphides at all.

Raphides, fig. 57.—These are the well-known needle-shaped crystals occurring about a score in a bundle, either plainly in a soft cell, as, *e. g.*, in the berry of *Arum maculatum* (fig. 57, *c*), or in intercellular spaces, without an evident special cell, as in old fronds of *Lemna trisulca* (fig. 57, *f*), or devoid of any distinct cell or intercellular space, as in the ripe berry of *Tamus* (fig. 57, *e*). However this may be, the raphides, before they have been disturbed, always lie loosely in contact, side by side, like needles in a packet; and so no wonder that they have been named from a Greek word signifying a needle. The shaft of each of the raphides is commonly smooth and rounded, so that they move easily on and over each other; and it tapers gradually to a point at each end. Raphides have an average length of about $\frac{1}{124}$th of